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RESEARCH IN THE
UNITED STATES FOREST SERVICE
A STUDY IN OBJECTIVES

FROM
"A NATIONAL PLAN FOR AMERICAN FORESTRY"

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RESEARCH IN THE UNITED STATES FOREST SERVICE, A STUDY
IN OBJECTIVES

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CONSOLIDATION AND SEGREGATION

The Branch of Research was established in the Federal Forest Service on June 1, 1915, by Henry S. Graves, who was then Chief Forester. This action was a part of a more or less sweeping reorganization of the work of the Department of Agriculture which began a few months earlier. The general purpose of the departmental reorganization was in the words of the order putting it into effect to obtain "greater efficiency by definitely outlining or segregating within each bureau" the three main departmental activities, regulatory, research, and extension. While the Forest Service has little or no regulatory work in the commonly accepted sense of the term, it has instead a large administrative responsibility for the handling of the national forests.

The establishment of the branch of research involved the recognition by the Forest Service, among other things, of the following:

1. The need for forest research, if the main responsibility and objective of the Forest Service to bring about the full use of all forest lands of the United States and of its products and services is to be met.

It was a recognition of the fact that only by means of research would it be possible to obtain in the shortest possible time and at the lowest possible cost the basic knowledge necessary: To bring about the productive use of forest land for timber growing; to place and keep forest products in a position to compete with other materials in present-day industry—which is relying more and more upon research—and thus to insure a demand for the products grown; to insure the full recognition and use of forests and other vegetative cover in the regulation of stream flow, the prevention of erosion, and

the production of water crops or the combination of water, timber, and forage crops; to bring about the productive use of forest ranges for the grazing of domestic livestock where consistent with timber growing and watershed requirements; to put the forest in a position to meet the growing needs for recreation; to obtain full recognition of its function as a home for wild life; and in general to make forest lands and forests render the largest possible economic and social service.

2. The Federal obligation and hence that of the Forest Service for the part of this research consisting primarily of national, interstate, and regional problems regardless of land ownership, and also of more local problems of the federally owned national forests.

The Federal obligation is based upon the need for making the national forests, which constitute more than one sixth of our total area of forest lands, of maximum public service. It is based upon the possibility of insuring profitable use for the five sixths of the forest land now largely in private ownership. It is based upon the need for finding more profitable use in forests for an area of submarginal agricultural land which may aggregate as much as 80,000,000 acres. It is based upon the fact that many forest problems have important national, interstate, and regional aspects. It is based upon a growing appreciation of the size and complexity of the entire forestry enterprise, upon a critical time element, and upon the need for national leadership which the Federal Government alone can furnish. In short, the Federal obligation has many things in common with that in agriculture proper which is the justification for a large amount of work in the Department of Agriculture. The concentration of much of the Federal forest research in the Forest Service is the direct result of the concentration in the Forest Service in large part of the responsibility for the forestry activities of the National Government.

3. That, most satisfactorily to meet the need for forest research and the Federal obligation for a part of it, as well as most satisfactorily to meet the needs of national-forest administration, research activities in the Forest Service must be consolidated and administrative and research activities must be segregated; that research work and personnel must be given a status equal to those of other Forest Service activities; that the activities concerned "should be so organized and related that each will reinforce and foster the other."

Research of a general or extensive character was one of the earliest if not the first activity of the organization which, in 1905 with the transfer of the national forests from the Department of the Interior to the Department of Agriculture, became the Forest Service. During the 10 years following the transfer, the great task of placing the national forests under administration so completely absorbed the thought and activities of the Forest Service personnel that research was very largely ignored. By 1915 it had become almost wholly submerged in the effort to administer the national forests. It was scattered in several branches, the primary responsibility of which was national-forest administration. Research in silvics, for example, was in the branch of forest management; range investigations were in the branch of grazing; field stations except the Forest Products Laboratory and the range stations reported to administrative officers in charge of national-forest districts; separate stations were main-

tained for each class of work even in the same region and consequently correlation was extremely difficult. For forest-products research alone there was a separate branch organization devoted exclusively to research, but even in this case final responsibility rested in an assistant forester in Washington whose main responsibility was national-forest administration.

Research was so submerged, in fact, and so out of the thought of the rank and file of Forest Service personnel that its development was practically at a standstill. In organization, administration, finances, the selection and recognition of personnel, and in practically every other particular it was subordinated to the development and administration of the national forests.

Progress made prior to 1915 in spite of the handicaps of organization, has been invaluable in the subsequent development of research. The Forest Products Laboratory, thanks mostly to much greater administrative freedom, had been developed to essentially its present form. Several small forest experiment stations had been established in the West, local in their conception and designed primarily to serve national forest needs, but still experiment stations. Most of them were essentially the same as our present experimental forests. A handful of men had been developed as a nucleus around which to build a larger staff. A good deal of exploratory work had been done and substantial progress had been made in working out specialized technique adapted to the requirements of forest research. In many respects seed had been germinated which needed only the right kind of opportunity for growth and fruition. The development of research prior to June 1, 1915, is, however, an interesting and important story in itself, the telling of which will not be attempted here.

The reorganization of June 1, 1915, met the situation by recognizing research as a major Forest Service activity on a par with other activities, and like them, one which must stand on its own feet. It met the situation by segregating both administrative and research activities. The basic purpose in the Forest Service, as in other bureaus of the Department, was the greatest possible efficiency and the largest possible public service in both activities in the broadest and most far-reaching sense.

Under the plan for consolidating research activities and segregating administration and research, the Forest Service organization, in briefest terms, took the following form: The forest experiment stations became responsible for the organized research in specified regions, the Forest Products Laboratory for the work within its particular field over the entire country, and all reported directly to the Branch of Research, which in turn reported to the Forester. All the national forests in each of the several large regions continued to report to a district or regional office, which in turn was responsible to the Forester. This means that there are two sets of field organizations which have been made responsible for research and administrative work respectively in the same territory and which report independently to Washington.

Experience has shown that the gains to research through consolidation and segregation have far more than offset possible losses. One of the greatest losses has been through the elimination of such advantages as might accrue through the administrative handling of the work by experienced executives, men of ability who have risen to responsible positions.

One of the most important gains has actually been in supervision, although in some cases temporary dependence has been necessary upon much younger men or men with less supervisory experience. Forest research even in a preliminary or extensive form is specialized, and as the work increases in intensity becomes more and more highly specialized and over a widely diversified field. Supervision to be effective must be equally specialized. It must be highly sympathetic in order to insure the right atmosphere and the best conditions for work, and to obtain the most and best results. To give supervision of this character calls for men with research training and experience and background. It must have the major call upon their time and interest. It must be the main job of men who are responsible for research alone. Such supervision cannot be obtained as a side issue or an incidental interest. In fact, thoroughly competent and fully sympathetic supervision is one of the main essentials for effective research. The Forest Service learned through experience that, regardless of their ability, it could not and should not be expected from men whose main job was the administration of the national forests and whose experience, interest, and outlook were primarily or exclusively that of national forest administration.

One of the incidental gains to research from segregation has been to relieve investigative personnel of a large volume, in the aggregate, of miscellaneous incidental jobs which formerly detracted materially from their main effort, or research. They have been relieved from the necessity of being "handy men."

The segregation of research has meant freedom from pressure to justify the administrative practice, technical or otherwise, in use on the national forests. In many instances it has already led to the recognition of the investigative staff by the general public, and by financially interested sections of the public, as a wholly impartial organization. The importance of freedom in research to reach conclusions based on facts cannot be overestimated.

Probably the most important gain has been in the freedom to formulate objectives and to develop the research organization and policies to meet the specialized requirements of investigative work. These necessarily differ from national forest administration in such important respects as recruiting, financing, and many phases of supervision. This may sometimes have led to the feeling in the larger administrative group that such changes in policy or procedure, which had been developed in the Forest Service purely and simply from the administrative standpoint and regardless of how poorly they applied in investigative work, were unjustified and wrong in theory and practice. It has been at bottom, however, a recognition of different fundamental requirements for the most efficient conduct of two distinct classes of work having a single and very broad ultimate objective.

Experience has also shown that the gains to administration from segregation have far more than offset possible losses. The greatest of these gains has been from the far more rapid development of research and from a far greater volume of information as a basis for a sounder national forest administration. The existence of a strong research group, critical by the very nature of its work and free and independent of the administrative force, has been and cannot help but be a wholesome influence on national forest administration. It is one of the

best long-time safeguards which could be devised for preventing national forest administration from getting into ruts. On the other hand, the presence of an administrative group having no direct responsibility for research but needing its results and certain to be critical if it does not get them, is likewise a wholesome influence on the investigative staff. It compels research men to keep in mind that their function is service and that research is not an end in itself.

DEVELOPMENT OF ORGANIZATION AND FACILITIES

One of the problems resulting from consolidation and segregation, and one which has required a large amount of attention, has been the development of a sound organization in the broad sense and of effective administration as a means for doing the work for which the Branch of Research was established. This has involved such objectives as the most effective relationships between research and the administrative organization of the Forest Service, the most effective field units, the most satisfactory working facilities, adequate financing, a competent research staff, and effective supervision.

Organization and supervision are only necessary means to an end in research, and all objectives formulated for them must have this in mind. In general the more that organization and supervision can be kept in the background the better, and early settlement and settlement along sound lines of the questions involved is the best way to accomplish this. Sound and clear-cut objectives in organization and supervision help to insure a minimum of lost motion and the maximum progress and accomplishment.

THE MOST EFFECTIVE RELATIONSHIPS BETWEEN RESEARCH AND ADMINISTRATION

So that under the segregation plan administration and research would foster and reinforce each other in fact as well as in theory, it has been necessary to develop ways and means for maintaining the most effective relationship between the organizations responsible for the two activities.

One necessary means to this objective is that administration have a voice in the determination of what research should be done. Administrative officers have, therefore, been given a substantial share in formulating the programs on which the research is concentrated and also an opportunity to read and criticize reports covering investigative results. In other words, the segregation of research has been complete for the determination of research technique and the current administration of the research itself, but the work is on programs jointly recommended by administrative officers and the investigative staff.

A second means to this objective is provision for cooperation in getting investigative results into practice on the national forests. The administrative staff is responsible for application but can and should be aided by the investigative staff. Among the many forms which such aid takes are representation on boards which decide upon the details of the silviculture to be used in the cutting of national forest timber, on boards which review the handling of serious forest fires, attendance at conferences called to work out policies and technical management, assistance in special training camps for the administrative staff, etc.

A third means to this objective is provision for cooperation in getting investigative results applied on privately owned lands, or still broader, of furthering the practice of forestry on privately owned lands. Both the regional administrative organizations and the regional forest experiment stations have a very definite responsibility in these fields, although that of the former units is mainly to administer national forests and that of the latter is for research. In short, there is an overlapping of responsibilities in the relationships to the private owner and to the public in general which requires correlation. It is difficult to draw any clear-cut line between these responsibilities, although it has been clearly recognized that the major responsibility rests on the administration organization. With segregation of administration and research, as worked out by the Forest Service, satisfactory public contacts, including extension, must depend for success upon the good sense of the local Forest Service representatives directly concerned and upon a reasonable amount of give and take. The competitive element in the situation rightly handled has been and should continue to be stimulating and wholesome rather than injurious.

Still another means toward this objective is that both the administrative and research organizations contribute to major Forest Service policies. To this end major policies, regional and national, whether they involve administration of the national forests, relationships with private owners, or the conduct of research, ordinarily receive joint consideration.

Endless circumstances throw the administrative and research groups together in Washington and the field. Joint committees select on the national forests the areas for experimental forests and ranges and natural areas. The handling of experimental forests and ranges after selection is in some respects a cooperative undertaking. The committees which recommend programs for future research review the results of past research even before they are put into report form. Both research and applied forestry go forward simultaneously on many national forests. Junior foresters and junior range examiners are sometimes loaned from the administrative organization to research units. There is some exchange of personnel between the two classes of work, with the present trend mainly from administration to research, and of younger men for whom some administrative experience is a splendid background for a subsequent investigative career.

A final means to the objective of having administration and research foster and reinforce each other is afforded by the opportunity for having the two groups join forces in the occasional large undertakings that affect the whole forestry movement and that require for their most effective handling the knowledge, background, and experience of both groups. Congressional requests such as the Capper Senate resolution of 1920 and the Copeland Senate resolution of 1932, which require the broadest kind of consideration of the entire forestry field and the formulation of programs to meet outstanding national problems, illustrate undertakings of this character.

MOST EFFECTIVE FIELD UNITS

With the obligation for work on national and regional problems requiring investigations in all or nearly all forest regions of a country

of continental size, concentration of all research of all classes in Washington or any other one place is obviously out of the question. Some decentralization and the establishment of some field units is called for. One vital organization question involved in the formulation of objectives has therefore been the determination of what kind or kinds of field units and how many of each should be established, and what their general organizations should be. The establishment of such field units is so far-reaching in its commitments as to time, costs, and the character and volume of results that it has been absolutely necessary that it be based on sound fundamental principles.

One of the most important basic principles taken into account has been the interrelationship and essential unity of all phases of forestry and hence of the research upon which the forestry enterprise must depend. For example, natural reproduction in ponderosa pine stands on the Coconino Plateau in the Southwest depends partly upon precipitation and other climatic factors. Abundant reproduction can be obtained only through the rare combination of an abundant seed crop followed by a year favorable for survival of the seedlings. Soil is another important and very complex factor, as is also competition of larger trees both above and below ground. In this particular part of the range of ponderosa pine, damage to forest reproduction from livestock grazing may be very severe and the conditions under which it occurs and the grazing management necessary to prevent it must be taken into account. Range use obviously depends upon the character and amount of the forage or subordinate forest vegetation, and this in turn is frequently an important competitor of forest tree seedlings.

Campaigns for the destruction of predatory animals are carried out to reduce losses of livestock, and apparently result in increased numbers of rodents, some of which consume large quantities of forest tree seed, others destroy small seedlings, others, such as porcupines, destroy large seedlings, saplings, and even larger trees, and still others feed upon forage plants. Game animals are related to forest perpetuation on the one hand and to range use on the other. Both range use and forest reproduction are definitely tied in to the necessity and the ease or difficulty of fire protection. Both entomological and pathological problems are almost inevitably involved in very complex and far-reaching ways. The conditions, such as density of stand, etc., under which timber is grown, have a very direct influence on both the quantity and the character or quality of the forest products produced. Any form of forest or range or game management modifies natural conditions, and sets up a chain of biological sequences which is likely to carry through the entire forest complex. And all of these things are reflected in the requirements and nature of research. All phases of management have their economic aspects, which in themselves are interrelated and which must also be reflected in research.

Under the southern rim of the Coconino Plateau another group of relationships and hence another class of forest research comes into the picture—the influence of vegetative cover on erosion and stream-flow. The vegetative cover may be virgin or cut-over forest, or it may be that which follows the timber on devastated forest land. It may consist of chaparral or brush, or of forage grasses and other plants in the subordinate vegetation, or of different combinations of these. The brush and forage cover may have been materially

changed through grazing. The water crop on which the Salt River Valley now depends promises to become an important or even the sole purpose of forest and range management in some parts of this rim country. Where it is the main purpose, specialized silvicultural measures may become necessary. The same thing may be true of range management. Where either is true it will be reflected in the research required.

The same kind of interrelationships and hence essential unity holds true of practically every broad forest problem in every type or region in the United States. Any plan for research units which ignores this interrelationship and unity cannot be otherwise than unsound.

It is essential to recognize as a second principle that whereas for some research, such as most forest products investigations, the materials to be investigated can be easily and cheaply transported to a central laboratory from all parts of the United States and centralization may be a distinct advantage by aiding correlation, for other forms of research too great distances may result in lack of contact with and knowledge of field conditions which should govern the character of investigative programs. In silvical or forest range or erosion-streamflow investigations, much of the work can be conducted only in the woods. In such work, in a country like the United States, distance becomes a factor which cannot be ignored.

The responsibility of the Federal Government for national and regional problems requires the recognition of a third principle, the establishment of units which will facilitate work on these problems and tend to minimize or exclude work on local problems, for which, elsewhere than on the national forests, State and other agencies are responsible.

A fourth principle calls for units which will insure the most effective administration at the lowest feasible cost. This necessitates a happy medium between units so large as to be unwieldy and so small as to be ineffective. It requires workable units in reasonable numbers instead of too few large units or a multiplicity of small units. It means units which will hold costs for overhead equipment, etc., to a feasible minimum.

The application of these principles has resulted in two classes of field units, and the formerly rather numerous units which did not fit into either class have gradually been eliminated. One of these classes is necessarily regional and the other is national.

The first class includes the regional forest or forest and range experiment stations. The plan has been to locate one such station in each of the important forest regions of the United States. Since for much of the work the woods or the range must constitute the laboratory, distance is one controlling factor. Even under the regional plan it is often great. For example, the territory of the Southern Forest Experiment Station is 1,100 miles long by 400 to 700 broad, and by the best rail connections it is a 36 hours' journey from the New Orleans headquarters to the southern tip of Florida. The Central Station territory is 800 miles long by 750 broad, and it is 24 hours by train from the Columbus headquarters to the western boundary of the region. The California territory is 815 miles long. In general the regions adopted are not so large but that all parts can be reached in a reasonable time and cost.

The principle of unity of all phases of forestry and hence of forest research is being recognized in two ways in the regional forest experiment station plan. The first is, so far as a rather complicated forest distribution permits, to draw the boundaries of each territory to include similar forest conditions. The second is to concentrate all kinds of research in each region at one station. As a result of the latter the work of the stations includes silvicultural or forest-management investigations, range investigations, studies of erosion, streamflow problems of both forest and range lands, studies dealing with forest economics, and in a few instances investigations dealing with purely regional forest-products problems. Recognition of the principle of unity means the best opportunity for the coordination of interrelated classes of research and the prevention of duplication. It means many-sided, well-rounded-out group attacks.

For reasons which are so obvious as hardly to require explanation, the regional stations also constitute the most effective units for the recognition of the third principle of Federal responsibility for regional and national problems. For the classes of work handled by the stations they are finally the most logical units to insure effective administration at the lowest feasible cost by avoiding both excessive size and excessive numbers.

Since the creation of the Branch of Research in 1915, six such regional stations have been established in the East, and five local stations in the West have been reorganized on a regional basis. Plans call for one or two additional stations in the United States proper and one each in Alaska, Hawaii, and the West Indies.

The second class of field unit includes only one institution, the Forest Products Laboratory, at Madison, Wis. The principle of unity is recognized by the concentration at the laboratory of a very large percentage of the entire Forest Service effort in products research, thus insuring correlation and effective group attacks. It is recognized further by a gradually increasing amount of work on borderline problems between products and silvics. The future promises to bring also a growing number of purely silvicultural problems which can be handled most effectively at a central laboratory such as can easily be developed and has long been planned at Madison as a part of the Forest Products Laboratory. It is apparent also that the economic problems closely related to the forest products field can be handled most satisfactorily from the laboratory.

Distance in most forest products investigations is of far less importance than in silvicultural and range investigations, because most forest products problems, such as timber testing and pulp and paper investigations, are of a character in which the investigative material can be brought to a single central laboratory without disadvantage and with material gain in efficiency and correlation. Concentration of the work at a single national unit tends to emphasize the principle of Federal responsibility for national and regional problems and to prevent work on purely local problems. The principle of the most effective administration at the lowest possible cost is also met most fully in forest products investigations by a single national unit.

The establishment of a single National Forest Products Laboratory in 1910 followed the trial over a period of years of regional or local laboratories, of which there were about 12, the first dating from 1891. Although such local laboratories have obvious advantages, such as

local interest and closer contact with local conditions, they were finally abandoned because of excessive costs in equipment and personnel, including overhead, difficulties in the correlation of research, etc.

Under the existing organization in the Department of Agriculture, some classes of forest research are assigned to other bureaus than the Forest Service, and the field units described have the further advantage of permitting cooperative effort and a unified, well-rounded-out or group attack on the entire forest problem. Under this plan forest pathologists from the Bureau of Plant Industry, have been assigned to the Forest Products Laboratory, and pathologists from Plant Industry, forest entomologists from the Bureau of Entomology, and biologists from the Biological Survey have been assigned to several of the regional stations. The number is being gradually increased. All work under the direction of their own bureaus.

Since the basic interrelationship and unity of all classes of forest research is becoming increasingly apparent, more detailed illustration of the manner in which it is being recognized is justified, although this will involve some repetition of what has already been said. It has been necessary to provide for forest products research at some of our forest experiment stations, primarily on problems which have important local silvicultural aspects, such as the utilization phase of selective logging or mill-scale studies. The work on silvicultural problems at the Forest Products Laboratory, already mentioned, has led to the establishment of a Section of Silvicultural Relations. One of the important problems on which this section is working is the biochemistry of naval stores, a borderline problem which might be assigned either to the Southern Forest Experiment Station or to the Forest Products Laboratory, depending upon exigencies of finances, personnel, etc. Both the regional stations and the Section of Silvicultural Relations are certain to work on physiological problems. The laboratory and the stations are already in numerous instances joining forces in working out the relationship between growing conditions and the properties and quality of the final product, and in time this will be true in practically every forest region. Research in forest economics must inevitably be conducted at both the regional forest experiment stations and the Forest Products Laboratory. The Forest Survey is a large and important economic investigation which illustrates the interrelationship between silvicultural and products investigations and bridges in still another way any apparent gap between the forest experiment stations and the Forest Products Laboratory. In some of its aspects, such as the determination of actual and potential growth, it is closely related to and in fact merges into, the silvical research of the experiment stations, and in other of its aspects, such as present and probable future requirements for timber, is closely related to and merges into the work of the Forest Products Laboratory.

The range and silvicultural investigations at the regional experiment stations run together in such projects as the adaptations of range management necessary to insure reproduction of species like ponderosa pine, and as the influence of the vegetative cover where forest and forage plants occur in combination.

The growing realization of this unity and of the necessity of providing for it in investigative programs, in the administration of re-

search, and in the organization of field units is one of the most striking lessons which has come out of the development in forest research in the Forest Service during the last 15 years.

The question is sometimes raised whether the regional forest experiment stations do not constitute a new national system of experiment stations with a different basic principle from that of the State agricultural experiment stations. Federal contributions to both agricultural and forest research take two forms—one of financial grants to the States, and the other, of direct Federal effort. In the latter the Department has over a long period of years been building up a strong, Federally supported and controlled research organization of which the regional forest experiment stations constitute a part. These stations are designed to meet the Federal responsibility for work on national and regional and national forest problems. If they give any appearance of a new and different principle it is only because the entire country has been covered in a plan-wise organization. The steadily growing volume of cooperation between the Federal and State stations is evidence of the fact that the two sets of stations constitute complementary rather than rival systems.

MOST SATISFACTORY WORKING FACILITIES

An essential requirement for good research is satisfactory laboratory and other working facilities, including headquarters. The determination of what facilities will best meet requirements constituted, therefore, another important question which had to be answered in the development of forest research. The answer constitutes another set of objectives.

The Forest Products Laboratory is maintained at Madison, Wis., in cooperation with the State university. It has, therefore, all the advantages from the standpoint of research of affiliation with a strong educational institution with a well-developed graduate school and an agricultural experiment station in both of which there is a large amount of research. The advantages, in brief, grow out of the stimulus which comes from the opportunity for formal consultation and informal contact with a large group of specialists in widely diversified fields and from the scholarly and research atmosphere of educational institutions. They grow also out of the opportunities for formal cooperation.

The university provided laboratory facilities for the Forest Products Laboratory for many years, until the organization completely outgrew the available space. Present needs have now been met and future needs anticipated by a recently completed Federal laboratory in the maintenance of which the university will cooperate. This, with periodic enlargements, should meet the needs for years to come.

The headquarters for the forest experiment stations have constituted another problem. Isolated headquarters were the rule in the early stages of our forest and range experiment station development, so that the men might live with their jobs in the woods or on the range—an unquestionable advantage. It was found, however, that small groups of men stagnated scientifically under such an environment, and the experience of other organizations has shown that even relatively large groups have the same tendency. The plan of isolated headquarters has therefore been abandoned, and headquarters have

been placed in cities and wherever possible in direct cooperation with universities.

The headquarters of 6 of the 11 regional stations so far established are maintained in cooperation with universities, namely, the Allegheny Station in cooperation with the University of Pennsylvania, at Philadelphia; the California, with the University of California, at Berkeley; the Central States, with Ohio State University, at Columbus; the Lake States, with the University of Minnesota, at St. Paul; the Northeastern, with Yale University, at New Haven; and the Southwestern, with the University of Arizona, at Tucson.

For forest and range experiment stations maintained at universities, headquarters laboratory needs are being met in varying degree by the cooperating institution. The situation at stations without university affiliation is as yet far less satisfactory.

The major part of the silvicultural and range work must, however, be conducted in the woods and on the ranges. This requirement is now being met by a clear-cut departmental as well as Forest Service policy and instructions for setting aside from the existing national forests and dedicating to research both experimental forests and experimental ranges. Where there are no national forests, provision for acquisition or other arrangements are to be worked out.

Each experimental forest is to be as fully representative as possible of the conditions in an important subregion. So far as can now be foreseen, from 5 to 10 experimental forests will ultimately be required in each forest region in the continental United States and a smaller number in outlying regions. The McSweeney-McNary Forest Research Act specifies 13 such forest regions in the United States proper and 3 in outlying possessions. The area of each of the experimental forests will range from about 1,500 acres as a minimum to about 5,000 as a maximum, exclusive of natural areas. Housing and incidental laboratory facilities are needed and are gradually being provided at the experimental forests.

The same general policy is to be followed in the establishment of experimental ranges. Provision is also made for natural forest and range areas to form a part of experimental forests and ranges wherever possible, and for such other natural areas as may be necessary throughout the country for research purposes.

To date 15 experimental forests and 2 experimental ranges have been set aside by formal proclamation. Sixteen natural areas have been set aside and are available for investigative purposes. About an equal number of experimental forests and natural areas are in advanced stages of selection and formal establishment. Conditions in practically every forest region of the United States are represented.

The policy of formally setting experimental forests and ranges and natural areas aside in perpetuity grew from years of experience in which it was found that even on the national forests widely scattered sample plots could not be satisfactorily protected, resulted in excessive costs, did not in many instances lend themselves to the intensive research which frequently becomes necessary before problems can be satisfactorily answered, did not lead to satisfactory correlation of findings, were most unsatisfactory for demonstration purposes, and gave unsatisfactory results in many other respects. Experimental forests and ranges, with the bulk of the field research of the forest experiment stations concentrated on them, should within a relatively

few years become invaluable for demonstration purposes as well as for the research for which they are primarily created.

From the somewhat scattered statements in the preceding pages regarding the component parts of a forest experiment station a more comprehensive picture may be drawn. A station consists for one thing of a headquarters in a town which serves for the permanent residence of the technical and clerical staff, which offers the opportunity for laboratory work, and which preferably permits affiliation with a high-grade educational institution with a strong graduate school. It consists also of a series of experimental forests each of which is as representative as possible of the conditions of an important subregion. Where range problems are involved, similar experimental ranges are utilized. These experimental forests and ranges are in fact branch stations at which the bulk of the field activities of the station are concentrated. Each station works on the problems of an entire region and covers silvicultural or forest management investigations, range investigations, those of forest and range influences, forest economics, and to a minor extent investigations of forest products, or all classes of forest research except those which can be handled best in a national unit.

To the stations also, wherever satisfactory arrangements can be worked out, representatives are detailed from the Bureau of Plant Industry for investigations of forest pathology, from the Bureau of Entomology for investigations of forest entomology, and from the Biological Survey for investigations of forest wild life.

ADEQUATE FINANCES

When the Branch of Research was established in 1915 only a relatively small amount of research was under way in the Forest Service. As the National Forest administration became more intensive and the forestry movement on lands in other ownerships gained headway, the size and complexity of the research job and the magnitude of the Federal obligation for even a part of it were gradually realized. With the rapid exhaustion of virgin timber supplies and relatively small effort toward their replacement, with the technique of timber growing largely unknown throughout the United States, with forest products at a decided disadvantage in competition with practically all other commodities because of lack of knowledge of their properties and how to use them effectively, and with enormous areas of land available for timber growing and apparently suitable for no other purpose, there seemed to be little question about the urgency of research. The conclusion was accordingly reached that the national interest required expansion of the work as rapidly as increased finances could be made available, provided, of course, that suitable personnel could be obtained and the organization developed to handle the work effectively. It had to be recognized that adequate finances constituted one of the main essentials or objectives for doing forest research. Before increased finances could be obtained, however, both the public and Congress had to be convinced that the work contemplated was actually necessary and in the public interest.

The effort to meet financial needs finally led, among other things, to the passage of the McSweeney-McNary Forest Research Act of May 22, 1928. In its broader aspects this legislation is the organic

act for forest research in the Department of Agriculture, with all that this implies in recognition, standing, etc. A group of objectives, including the scope of the research, the field units at which it is to be done, and the 10-year financial program in accordance with which it is to be carried out, are given the full authority of congressional enactment. From the standpoint of the development of research in the Forest Service this legislation ranks in importance second only to the consolidation of the work in the Branch of Research and the segregation of administrative and research activities in the Forest Service.

The merit of the policy of adequate financing is not likely to be questioned except during a serious economic depression when Federal receipts are at a low level, the burden of taxation is severely felt, and public opinion is striking out at expenditures in general without very much consideration of their necessity or promise. The results of the policy must be judged on the basis of whether a scientific foundation for forest-land use or the lowest possible Federal appropriations are more in the public interest, and of whether the required effort could have been made by any other agencies. Finally, it should be borne in mind that the increases in appropriations indicated below were made during a period when adequate funds were available and that the amounts are insignificant in comparison with expenditures for other public purposes, or with the values at stake.

For the fiscal year 1915, \$286,578 was available for all classes of research, and for 1932, \$1,793,300, not counting cooperative contributions which would add about \$100,000, nor \$900,000 for a Forest Products Laboratory building, nor about \$140,000 for emergency construction purposes at the forest experiment stations. The average annual increase in appropriations for the 14 years preceding the passage of the McSweeney Act was about \$55,000, while that for the 3 years, not including the depression year of 1933, following the passage of the act has been \$250,000. The rate of expansion may be indicated still more specifically by classes of work.

The appropriation for forest management research in 1921 was \$50,000; that for 1932 was \$562,000, an increase of approximately 11 times in as many years. The appropriation for forest economics in 1925 was \$25,800, while that for 1932 was \$355,000, or an increase of nearly 14 times in 7 years. During the 15 years from 1917 to 1932 forest products appropriations increased approximately 5 times from \$135,000 to \$641,300. During the 5 years between 1927 and 1932 range research appropriations more than tripled, from \$40,320 to \$130,000. The first appropriation of \$30,000 for erosion-streamflow research became available in 1930. That for 1932 was \$100,000.

The expansion of the larger field units has been in proportion. Funds available for the Forest Products Laboratory between 1915 and 1932 increased from \$130,744 to \$534,430. The Southern Forest Experiment Station was established in 1922, with an initial allotment of \$14,860 and the funds available in 1932 were \$180,800. The Pacific Northwest station handled its work in 1922 with \$7,040, and in 1932 was allotted \$167,300. In 1926 the California station expended \$7,085, and in 1932 was allotted \$141,680. The Lake States station was established in 1924 with an appropriation of \$23,555, and this had been increased to \$103,390 in 1932. Field stations other than the Forest Products Laboratory received in 1921 a total allotment of less than \$50,000, while in 1932 they received \$1,048,580, a twentyfold increase.

The character of expansion is indicated also by the establishment of new units or the reorganization of small local units to a regional basis, and by the initiation of Nation-wide investigative enterprises. The Appalachian and Southern Forest Experiment Stations were established and the Northern Rocky Mountain Station was placed on a regional basis in the fiscal year 1922. The Lake States and Northeastern stations date from 1924. The Pacific Northwest station was reorganized on a regional basis in 1925. The forest taxation inquiry was organized in 1926. The California station was founded in 1927. The Central States and Allegheny stations were established in 1928. The forest survey was initiated in 1930 and the Intermountain and Southwestern stations were established on a regional basis in 1931.

The increase in finances has carried with it the initiation of lines of work some of which had been recommended regularly over long periods of years. The Forest Survey, for example, for which the initial appropriation was obtained in 1930 under the authorization of the McSweeney-McNary Act, was first recommended some 50 years ago. Provision for intensive studies of forest taxation and forest insurance, dates from 1926 and 1930, respectively, following the authority granted in the Clarke-McNary Act. For other classes of economic work repeated recommendations had been made over at least a 10-year period, but it needed the authorization of the McSweeney Act to make the first appropriations available in 1930.

With growth in appropriations there has been a corresponding expansion in the Branch staff. It now totals approximately 500 of whom 285 are technical. The increase is not in the same ratio as that of appropriations because of changes in salary level.

Probably few foresters in the United States realize how even under its present inadequate status the provision for forest research in the Federal Forest Service alone compares with that in other countries. Although full data from other countries is not available, a check of all the sources at hand in 1930 indicated current expenditures in all other countries of approximately \$1,000,000. It is probable, therefore, that the 1932 appropriation of about \$1,800,000 for the Forest Service equaled or exceeded expenditures in all other countries. This is a situation which has developed almost entirely within the last 10 years, and a substantial part of it since the passage of the McSweeney-McNary Act. It is not an indication that requirements are being met. As will be shown later in greater detail, in every region and in every field of research the projects on which nothing is being done or on which the attack is seriously inadequate far exceed those on which it is now possible to work or on which attack can now be made on an adequate scale.

As the result of the current economic depression, some of the financial ground gained has already been lost. The funds available for the fiscal year 1933 are about 10 percent less than those for 1932. A prolonged depression may seriously threaten much that has so far been gained.

COMPETENT MEN

Long years of experience have shown the hopelessness and the futility of attempting to do satisfactory research with mediocre or poor men, and hence one of the main essentials in building up a

research organization is to have a thoroughly competent, adequately trained staff.

If the past few years prior to the depression can be taken as a criterion in Federal forest research, the possibility of obtaining qualified men, not the availability of money, has in fact been the controlling or limiting factor in the rate at which the work could be expanded. That the national requirements for forest research have not been met during the last decade is primarily because sufficient men with the necessary mental equipment and training have for one reason or another been nonavailable. The current economic depression raises a question as to whether this will continue to be true in the future—one which it is still too early to answer with assurance.

With men the limiting factor in the rate of expansion under normal economic conditions, either one of two decidedly different plans could be followed. Under one, appropriations could be sought and the work developed only as fast as well-trained and competent men became available in the natural course of events without special stimulus. This plan is commonly followed in developing research organizations. Most important among its advantages is probably the assurance of a better conduct of the research attempted. Among others, it is much less likely to lead to criticism, which is ordinarily of the way research is done rather than of the failure to do it on a scale commensurate with public needs.

The other plan was to make the requirements of the job, or in other words the public interest, the compelling consideration. The size, complexity, and urgency of the problem in the United States, or the public need, as indicated in the discussion of adequate finances, seemed to be sufficient justification under normal economic conditions for the expansion of the work as rapidly as possible.

But the adoption of the latter plan of making the public need the guiding principle in the development of research has created a difficult recruiting problem. In meeting this problem the requirements as to mentality for recruits to the investigative staff have been set very high. When sufficient men with adequate training could not be obtained, the balance of current needs have been met by the employment of men who have been only partially trained for investigative work. In short, the jobs have been created and made as attractive as the limitations of the Government service permitted in order to interest good men and to stimulate the training of such men for research.

The recruiting standards or objectives adopted call in every instance for obtaining the ablest man available in the forestry profession. Mentality, idealism, character, and all of the faculties and qualities which are necessary for the highest grade of research are taken into account. In training, the objective is a doctor's degree or an equivalent, but this is not as yet attainable in many cases. Efforts in the selection of every man even for the lowest junior positions go to great lengths. All the evidence which can be obtained from every possible source bearing upon qualifications is taken definitely into account. Such evidence is collected and contributed systematically to a central clearing house by every unit and every permanent employee in the organization. An effort is made to keep a running record of every young man in the profession whose work is outstanding. This goes as far back as the undergraduate record.

It has been found through systematic check that the civil-service record for junior positions is in the great majority of cases an excellent criterion of what may be expected in the subsequent career of individual men. Men who show up best in the junior examination almost invariably have a creditable subsequent career. Almost invariably the men who have failed to develop, who have become personnel problems, are those whose civil-service record is unsatisfactory.

Since it has been necessary, with inadequate numbers of fully trained men available, to employ substantial numbers of men before they are fully trained for research, training on the job has become an essential part of the effort to build up a research organization. That training on the job does not give some of the things that the schools do is fully realized, but if experience is any guide, its possibilities have been far too heavily discounted. Efforts for such training are made as systematic as possible, and include such things as care and diversity in research assignments, special supervision on them, details to other regions, special training for particular classes of work, etc.

Another move to stimulate the development of the investigative staff has been the discontinuance of year-long isolated headquarters, and location of the experiment station headquarters wherever the circumstances permitted, in direct cooperation with universities. Without doubt this has been a material factor in stimulating and broadening our personnel.

In recognition of the benefits of advanced college training for research, men who have not had such training have been encouraged at temporary sacrifices to the organization to go back for further training. Of the men in the research organization not yet fully trained a large percentage plan to take advantage of this opportunity at their earliest convenience.

Another phase of this effort is the temporary summer employment of forest school undergraduates. The number so employed annually already reaches from 75 to 100. The policy is to select only the best men, to develop in these men an interest in research as a career, to give them a background of research experience, and in general to make temporary employment one additional means of building up the ablest and best-trained staff available in the profession.

Practically no men were training for forest research in 1915 because there was little or no promise of a career if they did. The policy of placing public requirements ahead of other considerations in Forest Service research involved the deliberate creation of relatively large numbers of jobs. During each of the 3 years ending with 1932, men for 30 to 50 new positions were sought. The possibility of a career in research has been made as attractive as the limitations in the Government service will permit, as to salary, personal recognition for work done, desirable headquarters for permanent residence, etc.

As indicated above, the Forest Service demand for men has been one of the factors which within the last decade has revolutionized the situation in the forest schools of the United States equipped to give advanced training. The revolution has gone furthest in silvicultural work, but it has begun in forest economics, range, and other classes of research. Whereas 15 years ago, or even at the close of the war, there probably were not more than 2 or 3 men in the entire United

States who were studying for a doctor's degree in forestry, there were 32 men at 6 of our forest schools in 1929-30.

Five or six of these were in the field of wood chemistry and wood technology, several in the field of range ecology, and practically all of the others in silviculture and various aspects of forest ecology. Comparable data on the number of men working for master's degrees in preparation for research as contrasted with other phases of forestry are not available. Obviously the demand from other organizations than the Forest Service has accentuated the burden on the forest schools to supply in rapidly increasing numbers men thoroughly trained for the various kinds of forest research.

EFFECTIVE SUPERVISION

Another question involving the philosophy of organization and supervision which has had to be faced and settled, but which nevertheless keeps arising, is whether the work should be handled by individual or organized effort.

In many research organizations individual investigators under general or no supervision and with little or no coordination decide what they can and should do, follow out leads as they find them, and proceed without very much regard to what their associates are doing. Unquestionably this form of individual effort has many advantages, chief among which is the incentive arising from lack of restraint. It fails fully to take into account, however, such basic considerations as the need for group attacks because of the interrelationship of all phases of the forestry problem or its unity, and it fails to meet other requirements and responsibilities of a publicly supported research agency.

The plan of organized effort has accordingly been followed by the Forest Service. The determination of the programs on which work will be done is undertaken systematically once each year and programs so determined ordinarily remain in effect during the ensuing year. In reality the determination of such programs is an attempt to set up clear-cut objectives for a year's work. The members of investigative staffs are then assigned to the projects agreed upon in which it is believed, all things considered, they can render services of the greatest value. In short, wherever the nature of the work requires, the staff works as groups on those phases of the forest problem which, after careful consideration, are determined to be most in the public interest. This plan insures fully coordinated attacks on the most urgent problems, continuity of purpose and effort, and results of greatest value from the public standpoint, and, finally, makes it possible to render a satisfactory accounting to the public which finances the work.

Accomplishments to date under this plan unquestionably far exceed any conceivable progress under unrestricted individual effort. Furthermore, it has been found that sufficient leeway can be given for individual effort to satisfy nearly all investigators, individualistic though they may be.

The Forest Service handling of research differs in still another respect from that of many other research organizations in requiring that a carefully thought-out plan be put into writing for all the specific pieces of work or projects undertaken, at least after they have passed a preliminary exploratory stage. This for one thing makes it neces-

sary to think out plans as fully as possible in advance of beginning work, with whatever advantage this may bring in avoiding mistakes. It permits criticism from other men. The scheme as followed is perfectly flexible in allowing or requiring the revision of plans whenever the development of the work calls for it. Without question this requirement also helps to insure the fullest possible correlation of the investigative work as a whole.

Dependence upon public funds has led among other things to the adoption of the principle of accountability, and there cannot be accountability without pressure on men who need it for the delivery of reasonable results. That this principle is regarded by many research organizations as inapplicable in investigative work or injurious to it is well known. Without any question accountability introduces difficult problems of supervision. Zeal and interest can in the great majority of cases be appealed to in men of the right sort when important questions of public interest are involved. Men who have the ability to render satisfactory services and who have the public interest at heart are not the ones who object. Rightly handled, periodic accounting need not interfere with individual initiative and can be made as wholesome an incentive to good work in research as in any other human activity. In the last analysis the public that we serve has a right to ask that for every dollar expended at least an equivalent value in services be rendered and that appropriate means to insure this return be taken.

Finally, effective supervision requires conscious and continued effort to create and maintain the right atmosphere for research, the interest, the zeal, and in general the intangibles which are so large a factor in the character and quality as well as the quantity of work and which are perhaps more needed in research than in any other activity.

Organization, facilities for work, finances, men, and effective supervision are, however, merely a beginning. Taken alone they mean nothing. Singly and collectively they only pave the way for research. Research itself is only a means to an end. The end is human welfare.

PROGRESS IN RESEARCH AND THAT STILL REQUIRED

In the space available it is possible to discuss actual progress in research only in the most general terms. A compensating advantage should be a clearer picture of the broader aspects of the situation for the entire country. Because the major portion of Forest Service results have been obtained since the formation of the Branch of Research in 1915, the statement covers all results to date. The headings are by appropriation items and do not in all cases conform exactly to accepted professional terminology. The field which remains to be covered is discussed without reference to the obligation for it which rests on many agencies of which the Federal Government is only one.

FOREST MANAGEMENT

Forest management, one of the most important classes of forest research, determines how to establish, bring to maturity, measure, and protect forests or, in the broadest sense of the term, how to grow or manage forest properties. Research in forest entomology and

forest pathology, although essential parts of this subject, are not discussed because they are administered in other bureaus of the Department of Agriculture.

NATURAL REFORESTATION

Although planting has the greatest popular appeal, it is on natural processes of regeneration that the forester must very largely depend for the perpetuation of the forest. Accordingly the latter has received by far the greater emphasis in research. For a rather large percentage of the most important forest types in the United States, research findings to date show in a fairly satisfactory way how natural reproduction can be obtained or how to reestablish the forest by controlling the method of cutting the mature forest. Or conversely, they show for most of our more important forest types how to prevent the forest devastation which has been such a widespread evil in the United States; and also how to prevent forest deterioration, which has been a less spectacular but probably an even greater evil. Some of these findings, as for example in the ponderosa pine, Douglas fir, and eastern spruce forests, involve significant adaptations of the standard European silvicultural methods to the requirements of American species and American conditions.

The work done in this and other connections has in the aggregate accumulated a rather impressive knowledge of the taxonomy and distribution of our forest trees, of the life histories and requirements of many of the most important species, and of the ecological relationships of many important single species and forest types. The ground to be covered is far greater than that which has been covered, but much of our silviculture of natural forest regeneration is no longer entirely blind and without fundamental foundation.

Looking at our needs in a broad national way, a very large field of work in the reestablishment of forests or in obtaining natural reproduction still remains. Much of the information so far obtained is empirical and too little progress has been made in breaking the problem down into its constituent factors, which is a necessary preliminary to an intensive attack. Far too little, to illustrate, has been accomplished in breaking down problems of light, soil, moisture, competition, physiological responses to environment, etc., as a basis for the evaluation of these factors through intensive research.

Much less progress can be shown on the problem of carrying established forest lands through to maturity, although a good beginning has been made. Large numbers of sample plots have been established, but nearly all are still too recent to render their fullest value. Thinning plots and those representing other cultural operations are fewer in number. In general, the work along this line is in a preliminary empirical stage.

As in the initial problem of establishing the young forest, practically everything is ahead in breaking down into its constituent factors the problem of carrying established stands to maturity, as a preliminary to intensive attack. Large additional quantities of both empirical and intensive work will be necessary before we shall be in a position to say with assurance what are the best species and mixtures for various conditions of soil, etc.; how we shall manage our stands to insure quantity or quality production or the right combina-

tion of both; the best relationship between silviculture and protection against fire, insects; and forest diseases; the relation of silviculture to erosion, stream flow, and other forest influences. In general, the larger and more important question of bringing forest stands to maturity has had much less attention than that of establishing young forests and preventing forest devastation or deterioration.

ARTIFICIAL REFORESTATION

Research in artificial reforestation has made substantial progress in laying the foundation for fairly satisfactory nursery- and field-planting technique for our most common and valuable conifers. For these species, in other words, we have made substantial progress in learning how to grow forest tree seedlings and establish forest plantations. The availability of this information means that planting with the species in question has far greater assurance of success than it would otherwise have.

On the other hand, the work has barely begun on what is perhaps the larger and much more far-reaching problem of carrying plantations to maturity, the ultimate measure of success. Still ahead is the research necessary for growing forest crops of the best species and mixtures that will give highest yields, or the best quality for particular purposes, or a desired combination of quantity and quality. An enormous volume of work is required for practically all species, types, and regions on such problems as the source of seed, planting sites, mixtures, density, etc. This is the information on which we shall in the last analysis have to depend to avoid failures and to insure ultimate success in growing timber.

The work thus far on artificial reforestation has been almost entirely on conifers. The development of a satisfactory technique for establishing hardwood plantations lies ahead, as does also the work on which we must rely to bring such plantations to maturity.

Time is a very important element in practically all aspects of silvicultural research on either natural or artificial regeneration, or on carrying established stands to maturity. The results cannot be hastened. The life span of trees is very long. Extreme climatic conditions which may occur only periodically often have a decisive influence on the forest. The oldest silvicultural plots have been in existence from 20 to 30 years, many more from 10 to 15 years, and the largest number from 5 to 10 years. Because of the relatively brief time since the establishment of sample plots, the potential promise of results probably outweighs the results already obtained; but in spite of this there has been a great although as yet intangible gain in the passage of time.

FOREST MENSURATION

The work in forest mensuration to date can claim the preparation of volume tables for approximately 50 species, and of yield tables for approximately 12 forest types which normally occur in even-aged stands. American foresters need not apologize for their contribution to a better technique in volume and yield table construction. Neither do they need to apologize for progress in the use of statistical methods as a tool in forest mensuration and other forest research. Practically all of the work, however, has been done in natural as contrasted with

managed stands, although a small beginning has been made in the latter field through the establishment of permanent sample plots. Only a beginning has been made in the preparation of growth tables for uneven-aged stands.

Undoubtedly a good many years' work is ahead even within the fields touched upon in the preceding paragraph. The more intensive fundamental work on both volume and yields lies almost entirely ahead. Only a little has been done on the fundamental laws governing form or even on the first steps of breaking the problem down into its factors. Only preliminary information is available on the influence of such factors as wind, temperatures, soil mixtures, density of stands, cutting, etc., on form. The same general situation holds regarding the more complex yield problem. Even the conception of normal stands which has been the basis for much of our work to date on normal yield tables, is vague and poorly defined. Quality of the product, as contrasted with quantity, has as yet received practically no consideration in either volume or yield work.

FOREST-FIRE PROTECTION

Forest-fire research apparently originated in the United States, undoubtedly as the direct result of a forest-fire situation which is more serious than in almost any other country. Research of this character is gradually being taken up in other countries, and may now be under way in half a dozen. The problem is complex, and accordingly it is gratifying that progress has been made in breaking it down into parts that can be studied effectively.

Substantial progress has been made in the development of a technique for statistical studies of past fires and the efficiency of protective organizations. These and other studies are giving invaluable leads for improvement in fire control by pointing the way to better organization for the prevention of forest fires, for prompter detection, for extinguishing fires while small, and for the organization necessary to combat large fires. These studies are also paving the way to greatly improved hour-control or speed-of-attack standards, which is one of the essentials in the development of fire protection.

Studies of fire damage have proved invaluable as a means for combating the light-burning theory in several parts of the country where it has been a serious menace to forest management. Relatively little progress has been made, however, in an exact determination of what damage is caused by fire in all forest types and forest regions, which is one of the primary requisites for an intelligent distribution of protective funds and protective organizations.

With existing organizations many fires become large, and with the greatest possible gains in efficiency this may be expected to continue with a certain proportion of fires for years to come. Some effort has therefore been devoted to studies of the climatic and other conditions which influence fire behavior and of going fires, and corresponding progress has been made. A beginning has been made on forest fire meteorology with particular reference to electrical storms and to relative humidity. Progress has been made in a much more exact determination of the factors which may indicate bad or serious conditions. All of the work on fire behavior and on the factors affecting it looks forward as one important objective to the improve-

ment of suppression tactics and technique. To the same end scattered effort has been devoted to the development of power equipment to speed up work and to reduce costs by replacing hand labor, which to date has been so largely used in fire suppression.

In a relatively few instances research has indicated the possibility that it may be advantageous or even necessary to use fire as a beneficial agent in silviculture. Research of this character, however, lies almost entirely ahead.

The possibility that the menace of forest fires may be reduced through silvicultural management, and that under some conditions the maintenance of the forest cover by the elimination of clear cutting may be the most effective means of fire prevention, has only been touched upon. The work done, however, suggests rather far-reaching modifications of silviculture, and in fact for some forest types the probability that future silviculture may be dominated by requirements for fire prevention.

Forest-fire research to date has, on the whole, been centered very largely on man power, finances, organization, etc., to prevent and minimize forest fires and to extinguish them. In general, forest-fire research is still in its infancy, and its achievements lie mostly in the future.

OTHER CLASSES OF MANAGEMENT RESEARCH

Other phases of forest management in which research can make important contributions but in which as yet far too little or practically nothing has been attempted include: Forest regulation, involving rotations, cutting cycles, and cutting budgets, which have both silvicultural and economic aspects; forest engineering, including such problems as permanent road or transportation systems for forest utilization but having important silvicultural aspects, and as road and trail systems for fire protection; and park forestry and city and town or shade tree forestry, both of which have important root, physiological, growth, and health problems in which there is a large amount of public interest. Before forestry in the United States can be on a wholly satisfactory scientific foundation much information must be available for many species on the relative merits of geographical strains. This, along with other information, is needed as a basis of seed selection for planting. There is a distinct possibility also of developing hybrids which will be superior to any existing species.

FOREST RANGE INVESTIGATIONS

If not the first, the United States was one of the first countries to undertake range research. This work of the Forest Service grew out of the widespread use of western national forest ranges by domestic livestock and has since been extended by departmental or legal dispensation to include other forest ranges as well as nontimbered western ranges. The justification for the work is the possibility of using the range as one of the important products of the forest.

The Forest Service has centered its work primarily on the range resource and the relation of range used to timber growing and watershed protection, and has taken up the problem of handling livestock on the range only incidentally. The use of native plants in most instances as a secondary crop which must be perpetuated and controlled by natural processes and skillful use and, in the West, at least,

the necessity for handling livestock on open ranges of great extent in remote and rugged country, constitute markedly different problems from those of the ordinary cultivated pasture.

The work has resulted in the determination of the most important plants growing on the western mountain ranges as a whole, and has led to some general observational records of the forage value of different plants based upon the extent to which they are eaten by livestock. Aside from this it has so far been confined largely to the intermountain and the southwestern regions.

For a considerably smaller number of the more valuable plants in these two regions much more intensive information has been obtained on the growth habits, with particular reference to grazing use.

The work has developed some important general principles governing grazing use which apply with local adaptations to conditions throughout the entire West. Among these principles are the necessity for a very conservative stocking of the range on account of the striking decrease in growth of range plants during the periodical dry years or cycles; of allowing vegetation to make vigorous growth before being grazed; of giving bunch grasses periodic opportunities to reseed; of grazing sheep and goats openly and quietly and bedding them down in new places every night; and of obtaining better distribution of cattle on the range through well-placed watering places and better salting methods. A fair beginning has been made in a few localities on such fundamental questions as succession. Progress has also been made in determining the character and amount and also the cause of damage by livestock to forest reproduction and in working out forms of regulation to minimize or prevent damage.

The need for range research is by no means confined to the regions and types where it has so far been concentrated. Fortunately, increased appropriations made it possible to begin work in California and in the Northern Rocky Mountain regions during the fiscal year 1932. Investigations should at the earliest possible date be extended to other western types and regions and to eastern regions where, as in the South, range use now accompanies or can possibly accompany timber growing.

As contrasted with the long-time requirements of forest management for the growth of timber and cutting at intervals of several or many years, range management in the main involves the annual growth and use of annual or perennial plants. It requires knowledge which will permit the best species and mixtures of range plants to be maintained under use up to specified standards which must be determined. For depleted ranges it must also determine ways and means of restoration. Where timber production is the main objective, the possibility of range use depends upon whether timber can be grown successfully on the same area, and this must first be determined. The next step is the proper coordination of the two forms of use.

The more intensive research lies almost entirely ahead, and this among other things requires the breaking down of broader problems—plant succession, competitive relationships, soil productivity, physiological response to use, etc.—into factors which can be studied and evaluated in an exact way.

The large problem of range management will deal with native plants and natural revegetation. There is the opportunity, however, for artificial reseedling on which as yet only a few empirical tests have

been made, and for the development of improved strains, and perhaps hybrids, etc., on which nothing has been done.

FOREST AND RANGE INFLUENCES

The limited number of attacks on the erosion-stream-flow problem on forest and range lands in the United States, initiated prior to the last decade, dealt with watersheds or duplicate watersheds as a whole, whether forested or range covered. Valuable information was obtained, but much that was necessary to a real understanding of the role of vegetative cover, forest and otherwise, in erosion control and stream-flow regulation remained very obscure because of offsetting factors.

The present attack is in a few regions breaking this complex problem down into its constituent factors, such as the influence of the kind of cover (i.e., whether forest, chaparral, brush, or grass, or combinations of them), of the density of cover, of litter, of the character and rate of precipitation, of the degree of slope, or the kind of soil, or the requirements of transpiration, and is investigating each factor separately. Despite the fact that the latter phase of the work is only 2 or 3 years old, it is already giving extremely significant results, some of which go far beyond what foresters have ever dared to claim. The work on individual factors ought soon to lead to far more productive attacks on small and later on large watersheds than have heretofore been possible. Incidentally there is already specific reason to believe that detailed, exact measurements giving concrete results of the kind which the engineer is trained in and regularly deals with, such as are now coming out of the erosion-stream-flow work, may help materially to bridge the gap which has existed between the points of view of engineers and foresters on the forest-erosion-stream-flow relationship.

The Forest Service has done nothing on wind erosion and dune movement; relatively little on the relationships between forests and snow; has made some progress on purely local influences of shelter-belts in the plains region; and is only beginning to study the possibility of a general amelioration of climatic conditions over large areas.

Possibly one of the most valuable results of our erosion-stream-flow research is that while details are obscure or unknown, it has helped to give to us and to the profession a new and far better appreciation of the probable role of forest and brush and grass, or of the natural vegetative cover, on the whole erosion-stream-flow relationship. It has given a better appreciation of what forest and range deterioration or destruction probably mean in destructive floods, silted stream-beds and reservoirs, buried agricultural lands, water in the least usable forms for irrigation, and in reduced productivity of forest and range lands. It has helped to bring out the fact that water may in many instances already, and in many more instances in the future probably will be, the most valuable product of forest and range lands and that every other form of use must be regulated to this end. It has made us realize that this aspect of the forest and range problems in the United States is one of the most important with which we shall have to deal in future management, and that it is even more important in the formulation of land policies in the broadest sense of the word.

Possibly no other single phase of forest research is at present falling so far short of meeting national needs or offers a greater opportunity for constructive service.

FOREST PRODUCTS

When the Branch of Research was established in 1915 forest products investigations were better organized and financed and are still receiving larger appropriations than any other class in the Forest Service. Since 1910 the work had been centralized primarily in the Forest Products Laboratory at Madison, Wis., in cooperation with the State University, a clear-cut recognition of the organization which would ensure the best correlation of the work and render the largest returns nationally with the resources available.

METHODS OF HARVESTING

The utilization of forest products for most purposes starts with the cutting of the tree and here makes its direct contact with the silviculture that grows the tree. Significant but limited results have been obtained on methods of logging and the principles which underlie these methods, but logging and milling methods are now being investigated directly only in a special study of the small sawmill. The studies in this group have in general considered the use of standard logging and milling machinery and methods in determining the comparative costs of handling different-sized logs and trees of different diameters.

For about 15 species and 10 forest types very complete figures have been obtained on the cost and value of the lumber from trees and logs of different sizes, so that lumbermen and foresters can tell the minimum of tree and log sizes that will "pay their way." The purpose is to encourage, for future growth and the perpetuation of the forest, the leaving of the small trees that can be cut only at a loss.

In naval stores production, utilization begins with the wounding rather than the cutting of the tree. The work to date, which has involved both forest management and forest products investigations, has revolutionized methods of chipping and has given preliminary data on the yield from trees of different diameters, etc. Reference will be made here also to substantial progress on the relation of cell structure to the production of resin, and to the beginning of work on the biochemistry of resin production, although these investigations do not fall logically under the "harvesting" group.

Future work must provide for a considerable extension into other conditions of the determination of the size of the trees and logs which can be cut profitably and of the relationship between cutting for lumber and of utilization for other products, such as naval stores. A broad field, on which only a relatively small start has been made and which should be extended into all of the major conditions throughout the country, is the development of the fundamental principles on which logging methods, including types of machinery, should be based.

Logging methods up to the present time have been developed solely with the idea of getting material out of the woods at the lowest cost and with no reference to the silviculture which will grow new stands. Work along this line will in many cases require the modification of

commonly used methods, and in others require the adaptation of existing machinery, if not the development of entirely new machinery.

CONDITIONING FOR USE

The work so far done on the conditioning phase of utilization has consisted largely of the various problems connected with the drying of wood and particularly of lumber. That on kiln drying has progressed far beyond an initial study of different species with standard apparatus and methods. The principles of the kiln-drying process have been developed and applied in improving commercial methods and apparatus to the extent of practically revolutionizing such practices. The fundamental "how and why" of moisture movement in wood during drying have also been studied. Air-seasoning methods and results have been investigated. The work on methods of drying has been supplemented by investigations on allied subjects, such as the change in moisture content of dried lumber during storage and handling, the normal variations of moisture content of wood in houses, and rapid methods, including equipment, for determining moisture content.

A complete understanding of the "how and why" of moisture movement and of moisture relations in general is one of the most important and complex lines of research ahead in forest products and once obtained will have outstanding value in many different ways such, for example, as the further improvement of methods of kiln drying and air seasoning, the development of methods for treating wood which will prevent the absorption of or loss of moisture and hence shrinking, swelling, checking, etc. Similar work will undoubtedly be necessary on modified materials such as pulp and paper, and on some wood products other than lumber.

GRADING AND SELECTION

Lumber grading has been the first crude attempt to select or classify lumber according to value, and obviously value has some relation to properties. Grading has been based entirely on readily visible differences in amount and kind of defects without reference to properties other than those obviously affected by the defects. Except in the rules for structural timbers, the grades have borne no quantitative relationship to any specific property. Forest Service investigations on grading have been devoted partly to the relation between strength and grades in structural timbers, but mostly to the standardization of grading rules for different species, which have varied so widely and have been so complex that they have been very difficult for the public to understand or use.

Selection among species to obtain the best wood for every use is a much more important and complicated technological problem. In fact, it consists of such a large number of separate problems that only a few of them have been investigated directly. General information on the requirements for various uses, together with that on the properties of the different species, must be correlated to obtain proper selection. This subject will be brought up again under "Properties."

It will be apparent that a sound scientific basis is available for lumber grading only in part. The only product other than lumber

on which any work has been done by the Forest Service as a basis for grading is on pulps and papers, and such efforts have been confined to the last two or three years. Although lumber is one of the most important forest products, there are others in which there is need for a sound scientific basis for grading.

MODIFICATION OF PROPERTIES

Investigations of methods for the modification of the properties of wood such as durability against decay, fire resistance, and shrinkage, fall in this group. Perhaps, arbitrarily, such allied subjects as painting and gluing are also included. Modification of properties by drying has already been discussed. The logical order of attack is first the application of standard treating materials by standard methods to various species, and then the methods of application; but finally the treating materials themselves, the preservatives, glues, paints, etc., must be investigated and their properties correlated with properties of different wood species and the methods of treatment. The gluing and durability investigations have been in the latter stage for some time; the fire resistance and painting studies have recently reached it. The modification of shrinkage properties has been attacked in two distinct ways, the protection of the wood from moisture by moisture-proof coatings, and the treatment of wood by chemicals that reduce normal shrinkage. The first phase has been very thoroughly investigated; the study of the second is just beginning.

Since modification of properties may have to be so drastic that the original character and form of the wood is lost, it introduces another diversified group of products and hence of investigations. The most important example of this group is pulp and paper. The pulp and paper investigations, which began with tests of the pulp-making and paper-making qualities of practically all important American species under standard pulping processes, have now reached advanced stages of development. Intensive technological studies of the standard processes have now made it possible to increase their efficiency and to modify the processes to fit new species. Entirely new processes have also been developed. In reaching this advanced stage of research, greater refinement of method has been required, more accurate measurement and control, and attention to more details than in the preliminary species studies.

On the possibility of developing other modified forms, such as plastics, only work on a small scale and for a short period has been done. On many more modified products, such as artificial leathers, rayon, etc., nothing has been attempted.

A wide field for research still remains in modifications to prevent the absorption of moisture and hence shrinking and swelling, to develop satisfactory preservatives and treatments to prevent decay under all conditions, to develop economical treatments which will insure fire resistance, etc. In the pulp and paper field there is still room for vast improvement. It should be possible eventually to develop a number of the more common pulps and papers from many common tree species. Possibly ways and means can be developed to reduce excessive wastes in chemical pulping processes which are now responsible for the loss of approximately half of the original volume of the wood. Many agents, such as bacteria, fungi, etc., for the modi-

fication of wood have as yet received little or no consideration. Incidentally, it should be possible to work out methods for the prevention of undesirable stream pollution in pulp making.

In modern industry the general tendency which is becoming more and more rapid is to improve the properties of natural materials of all kinds through modification. Materials in their natural state, regardless of intrinsic merit, are facing more and more severe competition from other substances in which properties have been modified and improved, and this in such a way as to meet relatively exacting and varying requirements and specifications. For example, in an article on *Steel Takes Research into Partnership*, by E. E. Free, published in the December 1931 issue of the *Review of Reviews*, the following statement is made:

Dr. John Johnston, director of research of the United States Steel Corporation, recently listed 31 physical and chemical properties of steel which can be altered, more or less at will, by changes in chemical composition, in heat treatment or otherwise, to control the atomic structure of the metal.

Wood in order to hold its own in present-day and future competition must be given the same strategic advantage, and the only reasonable possibility of doing it successfully is by research.

DESIGN AND ADAPTATION

Design and adaptation cover investigations of those uses of wood in which the strength properties are most important. Increase in strength of unit pieces of wood by treatment has not been attempted, but instead the purpose has been by proper design to use at their highest efficiency the intricate normal strength properties of wood. This work of necessity includes not only the wood itself but also the various joints and fastenings by which the pieces of wood are held together, and which are a common and serious source of weakness. The most detailed and complete design work has been done on wooden airplane parts and on boxes and crates; in the latter field the work has already progressed to the final stage of determining the actual strength requirements of wood packages in service. A beginning has been made on house and other structures in the building and construction field. A large amount of investigative work has been done on such joint and fastening accessories as bolts, nails, and glues.

On the fundamental principles which must underlie improved design in building and construction, the field for research is enormous. Applications should be possible which will revolutionize construction both in form and costs and bring back to wood a part at least of the advantages which it has been losing during the last few years in competition with other construction materials. Building and construction, although the largest single consumer of lumber, is only one field requiring work. The availability of modified forms of wood, such as fiber boards, plastics, etc., create additional problems in design.

PROPERTIES

The foregoing groups of investigations consist largely of direct attacks on the practical problems of wood utilization. Investigations for obtaining the basic information required for proper furtherance

of the direct attacks may be regarded as falling under the broad heading of "Properties." This group includes not only the determination of the values for the physical and mechanical properties, but also special studies of the chemical composition and structure of wood and of the interrelationships of all these fields. Probably the most complete investigations have been carried out in the field of physical and mechanical properties. The strength properties, specific gravity, and total shrinkage have now been determined for all the important native species, and detailed studies have been made of various factors affecting strength, such as specific gravity, moisture content, and previous conditions of treatment or use. This basic information, together with the technique and experience gained in obtaining it, has been applied in the "Grading and Selection" and "Design and Adaptation" groups of investigations previously mentioned.

The field of chemical composition is much less definite and clear cut, both in its methods of research and in the use of the results. The comparative chemical composition of a number of species has been determined, and some work has been done on relationships between chemical composition and certain physical properties. In the present state of knowledge, however, chemical composition can be stated only in terms of various empirical groups or "constituents" such as cellulose and lignin that are in themselves variable and of only partly known composition. Much of the investigative work on chemical composition is therefore in the stage of developing methods for more completely determining the composition.

The investigations of structure have progressed far beyond the original stage in which the emphasis was placed on microscopic structure as a means of identification of species. Not only have advances been made in the character and detail of microscopic and sub-microscopic structure, but the field has been enlarged to include measurements of structure of submicroscopic sizes. Beginnings have also been made in determining the effect of these microscopic and submicroscopic structures on the properties.

Out of a real understanding of the chemical and physical properties of wood may well come some of the most revolutionary changes in the form and character of its future use. What has happened in the coal-tar field as a result of research is one example of the possibilities.

GROWTH CONDITIONS

The effect of growth conditions on wood quality involves both silviculture and utilization. Growth conditions vary so widely and there are so many kinds of wood quality that this is a very broad field of research. Only a few of the simpler and most readily controlled conditions of growth have as yet been studied, and the determination of the effects has been confined largely to the specific gravity of the wood.

The undoubted future trend toward a more and more intensive silviculture, and the increasing intensity of competition between wood and other materials which will tend to make the requirements on wood more and more exacting, will enhance the value of a thorough understanding of the relationship between growing conditions and the character of the final product.

FOREST ECONOMICS

One of the important classes of research in forest economics deals with the forest resource, which consists of such things as the stand of timber, the area of forest land, and the actual and potential growing capacity of the land. Within this field it has been possible since the World War to make three compilations of existing data for the entire country. The results, although largely approximate, have given a clearer conception of the extent of the resource nationally and regionally, and also of some of the sweeping economic changes which are affecting the forest problem with all others. Some data have been collected on the recreation, range, and game aspects of the forest resource, etc., but little on that of watershed protection.

A second important class of economic research deals with national and regional production or consumption of forest products and with requirements for these products. The collection of data on production or consumption has been under way for many years, largely in cooperation with the Bureau of the Census. The data are unequal in character, those on lumber, for example, being much more accurate and frequent than those on fuelwood, a product of importance second only to lumber in drain on the forest. Also constituting a drain on the forest are losses from forest fires on which approximate data have been obtained annually for a number of years, and from forest insects and diseases on which rough data have been compiled occasionally. From time to time also statistics of use by States or other local units have been obtained for most or all classes of forest products, but much less frequently and completely than those on production. Data have also been collected on recreational use, range use, and game production.

A Nation-wide forest survey was inaugurated in the fiscal year 1930. One purpose is to supply much more intensive and authoritative data than have heretofore been available on the forest resource. A second purpose is an intensive study of requirements. Since at the present rate the survey will require at least 10 years more for completion, it is important for many reasons that the work be speeded up. The desirability of keeping the data reasonably current after the work is first completed will be recognized, and this will require practically continuous but relatively small-scale work indefinitely for the entire United States.

Some of the problems of the forest industries are of sufficient public interest to justify investigation by publicly supported investigative organizations and constitute a third class of economic research. Work of this character has included more or less intensive studies of the lumber industry, including its economic status, the distribution of lumber, and various other public aspects, and of the pulp and paper industry, with particular reference to the possibility of obtaining future supplies of pulpwood much more largely or entirely from the United States.

A fourth general class of investigation deals with the economics of forest management and forest land use. Work to date has included a study, still in its early stages, of costs and returns from timber growing, or, in a broader sense, the financial aspects of forestry, in one important region, the South. This is an aspect of forestry on which information is very sketchy and unsatisfactory. Work

has also been done on prices and particularly those of standing timber, which are one measure of returns and hence of the incentive to grow timber. Taxation to the timberland owner is a cost, but to the public it is among other things an important source of revenue. Upon the formulation of equitable methods of taxation may depend in considerable degree the extent to which private owners embark upon timber growing. Following some extensive efforts in former years an intensive study of forest taxation for the entire United States has recently been under way.

A closely related group of investigations deals with various other aspects of private forestry—the progress which it has actually made, the determination of the factors which have interfered with its progress, constructive measures for removing obstacles, etc. This work has so far dealt primarily with conditions in the Pacific Northwest, where constructive measures of first importance are being worked out. If they materialize they will revolutionize methods of logging and silviculture and greatly reduce the fire hazard. An intensive investigation of forest insurance has also been started as an aid to timber growing by the private owner. Various studies have been made or started on land questions such as the economic effect of forest devastation in a limited region, and the extent to which a new public domain is being created through land abandonment, etc., together with the formulation of constructive measures for meeting the resulting situation.

The field for investigations which should supply the economic foundation for forest management and forest land use policies is very broad and of critical importance even under normal conditions, but much more so during periods of economic stress. The results of investigations such as those previously indicated, supplemented by other investigations as necessary, should in general determine the proper place of forestry and of forest land use in our local regional and national economic and social structure. The various kinds of work necessary can merely be illustrated, but among others would include: The economic basis for a classification of lands which should be devoted to forestry in contrast with agriculture or other uses; the basis for a classification of forest lands into those which should be utilized for the production of timber for watershed protection, for recreation, etc., or any combination of such uses; the basis for the best distribution of forest land ownership, Federal, State, or other public, and private; the manner and extent to which the public should contribute to or regulate the handling of private forest lands; the best combination of aid and regulation; the basis for sound policies of national forest administration and of lands in other kinds of ownership; and the economic aspects of rotations, cutting cycles, and cutting budgets, or broadly forest regulation. In fact, the field is so broad that practically no other line of investigative effort can be regarded as complete or satisfactory until its economic relationships have been covered.

OBJECTIVES, PAST, PRESENT, AND FUTURE

Whatever progress has been made during recent years in the development of an organization and the facilities for forest research in the Forest Service as well as in actually doing research and obtaining results, is largely due to two things. The first is the formulation of

objectives; the second, more or less aggressive and persistent efforts to reach them.

Outstanding among such objectives have been those connected with the establishment of the Branch of Research and those with the passage of the McSweeney-McNary Forest Research Act, both of which are in reality groups of objectives. Underlying these and nearly all other objectives is the recognition of the unity of the complex forest problem and hence of the various classes of research which must be used in its solution.

The most important aspect of the creation of the Branch of Research in 1915 was that it brought the research activities of the Forest Service together and definitely segregated them as a part of a general departmental reorganization which segregated its three main activities. It has been this more than any one thing that has given the first great impetus to research in the Forest Service. It has given to the investigative work and personnel a recognition and standing equal to that of other major Forest Service activities, something which they had not had at least since the transfer of the national forests to the Department of Agriculture in 1905. It has given for the first time the freedom needed for the consideration and handling of research requirements in the special ways necessary to meet investigative needs. It has meant for the first time a national conception of the need for forest research if all forest lands in the United States are to be utilized, of the Federal obligation for a part of this research, and of an aggressive, plan-wise effort to measure up to the Federal obligation. Accordingly, it led almost inevitably among other things to the passage of the Forest Research Act in 1928.

The McSweeney-McNary Forest Research Act formulates objectives in at least three particulars. First, it specifies what research may be done and attempts to cover the entire scope of forest research. Among other things this has made it possible to initiate the Forest Survey and other investigations in forest economics for which it had never before been possible to obtain appropriations. Second, it sets up a program of field units based upon such fundamental considerations as the interrelationship and unity of all phases of the forest problem and hence the necessity for well-rounded-out group attacks. This gives full legal sanction to the Forest Products Laboratory and the forest experiment stations already established, sets up authorizations for other stations known to be needed, and incidentally prevents the establishment of unneeded stations. Third, it outlines a 10-year financial program with restrictions as to total appropriations, which takes into account not only the national needs for research but the rate at which an efficient organization can be built up. The restrictions lapse at the end of the 10-year period and whatever appropriations may subsequently be necessary in the public interest are authorized. This act has been directly responsible for the first time in the history of forestry in the United States for appropriation increases even approximating national needs.

The background had been prepared by the work of the previous years for many of the remaining objectives which have contributed to the development and progress of research. But the clarification of nearly all of these objectives has resulted directly or indirectly from the two outstanding groups connected with the establishment of the Branch of Research and the passage of the McSweeney-McNary Act.

Among the remaining objectives are working facilities necessary for the most efficient conduct of research, such as experimental forests and ranges, the setting aside of which is now for the first time moving forward satisfactorily; laboratories, of which the new Forest Products Laboratory Building is outstanding; and the headquarters for field units which will be most effective in stimulating the development of the investigative staff, with 7 out of 12 such headquarters now maintained in close cooperation with educational institutions. Among them are also the highest possible standards for recruiting, which are bringing into the Research organization a group of the most promising men obtainable in the American forestry profession and which also are playing an important part in stimulating the training of men for research and the development of forest schools to give this training.

The annual programs required of all the Research units are nothing more than objectives for a year's work consciously designed to concentrate attacks on the problems which are most important and urgent from the public standpoint and to insure continuity of purpose. The policy of organized rather than individual attack on the problems selected is merely one means to the most effective carrying out of objectives. Written plans on each phase of the work or project are objectives for the investigative attack itself.

The unity of the complex forest problem and the interrelationship of all of its phases which run through and underlie most if not all of these objectives have been recognized by the establishment of the Branch of Research, which brought scattered investigative activities together; by the Forest Research Act, which treated these activities as phases of a closely related whole; in the fundamental principles of organization of the forest experiment stations, which brought groups of these activities together for specific forest regions; and in the principles of organization of the Forest Products Laboratory which brought together activities in its particular national field. They have been recognized in special provisions for coordination of effort in the twilight zone between forest management, forest range, and erosion streamflow; in forest products investigations; in the Forest Survey and other investigations in forest economics; in the coordination of effort in all classes of research by means of annual programs for each field unit, and in well-rounded-out group attacks rather than individual effort. The ways in which this unity must be recognized grow constantly. Recognition of it is one of the outstanding lessons of past work and consequently an objective which must be taken into account in all future plans.

The value of objectives should not be judged solely from progress in developing an organization and facilities for research in the Forest Service, because they are merely means to an end. A more important objective than either is the research itself, and a still more important objective is results which will aid and stimulate the development of forestry. But research results themselves are only a means to an end. The ultimate objective is the actual use of the results for human benefit. While investigators have a real but incidental responsibility for getting their results into use, the final responsibility rests on others, on the owners and managers of forest lands, and on the stockholders and executives in forest industries.

The investigative findings on practical methods of both natural and artificial regeneration of forests, on the life histories and require-

ments of trees and types, on volumes and yields, and on the control of forest fires have added to the assurance and certainty of efforts made to grow, protect, and manage timber. So far, the publicly owned national forests are the chief beneficiaries from the application of these results, but here and there also is a private owner. On the national forests application is at its best in fire control, for example, and follows research findings even before these have been recorded in progress report form, and in some instances the same is true of silvicultural methods.

The main contributions of forest range investigations, knowledge of the range plants and of their growth habits and forage values, the determination of a few important principles of range management, and, finally, the relationships between range use and forest regeneration, have also found their main application in national forest administration. Improvements in herding and bedding methods for handling sheep have, however, been rather generally adopted by the livestock industry on other ranges.

By far the largest application of the rather meager but significant findings to date on the indirect influences of forest and other forms of wild vegetative cover has also been on the national forests and for the use of forest or other cover as a means for controlling erosion or regulating stream flow by many municipalities and here and there a private corporation. The findings have to some extent been responsible for efforts toward sounder policies for other forest and public domain administration.

In the forest-products field, progress has been greater and more diversified mainly because larger funds have been available. The benefits from application in the forest industries, which have been very large, soon reach the ultimate consumer at one extreme and the owner of forest land at the other. And the public which owns the National and State forests is by far the largest single owner. Kiln drying of lumber has been revolutionized, as has also preservative treatment of wood against decay, the technique of naval-stores extraction, and wood-container design. Large numbers of pulp and paper mills are using improved pulping processes, several new mills have been built to utilize new processes, and the number of species in common use is gradually being extended.

The data on strength properties for nearly all American species and the factors, such as moisture, which govern them have been determined and are being rather generally applied. A scientific basis for the grading of structural timbers has been adopted for a limited number of species, and worth-while contributions have been made to the standardization and simplification of lumber grading. Principles of design in houses and other forms of building construction and in joints and fastenings have been less fully worked out and much less widely applied than those for containers.

Results which have not yet gone far enough for extensive application include the breaking down of wood into component groups such as cellulose; the microscopic and submicroscopic study of structure and the relation of structure to properties, and studies of the relation of growth conditions to specific gravity and hence to strength.

The economic data obtained in the three extensive forest surveys of the entire United States and other economic studies are more or less widely used as a background in the formulation of forest policies,

National, State, and otherwise, and also in attacks on them. The conclusions in extensive studies of forest taxation, which preceded by several years the intensive study now in process, are reflected in many State laws.

Since the major part of the development of research in the Forest Service has come since the war and chiefly during 1930-32 much of the work has been under way too short a time to produce results. For much of this uncompleted work the value of setting up and working toward objectives can only be judged in the future.

The reader is perhaps in a better position than those who have been engaged in the effort, to judge whether the progress made in the development of an organization and facilities for forest research has been worth while. He is also perhaps in a better position to judge whether the progress in research itself has been worth while, but must give full recognition to the fact that what has been done constitutes only the barest kind of a beginning. Finally, he is in a better position to judge whether the progress in the application of results has been worth while, although it must be recognized that application almost inevitably lags behind the knowledge available.

If the verdict is that worth-while progress has been made, the formulation of objectives and efforts to reach these objectives have justified themselves; and the most important of these objectives, the plan of bringing together and of segregating investigative activities, which was the essence of the creation of the Branch of Research, has justified itself. So also have the efforts which led to the formulation and passage of the McSweeney-McNary Forest Research Act, and the recognition of the unity of the complex forest problem and hence of the different classes of research which must be used for its solution. If worth-while progress has been made, one of the chief lessons of the past is, therefore, the value of objectives and of steadfast, persistent efforts to reach them.

A severe economic depression is possibly sufficient justification for caution in announcing if not in making far-reaching plans for formulating additional objectives. If the use of all of our land in the United States and the development of all of our industry had been plan-wise, however, we might have escaped the present depression. A possible means of minimizing if not eliminating future depressions may lie in the right kind of planning. The making of plans or the setting up of objectives for the future is in a real sense an expression of faith in the future of the United States and of preparation for it. The creed of the forester and the very nature of forestry require the long look ahead and in themselves justify the setting up of far-reaching objectives. All of these things apply in research as much as in any other phase of forestry—and to research with particular force if the progress of the last decade and a half and the reasons for it have been correctly interpreted.

Five years' experience has shown some deficiencies in the McSweeney-McNary Forest Research Act. Forest influences now demand a recognition which probably could not have been obtained when the act was passed in 1928. A bill introduced in the Seventy-second Congress adds a new section which rounds out the original provisions by providing more specifically for erosion-streamflow investigations on forest and range and other wild lands, and puts this work on its own feet as to legislative authority and financial

plan. By providing for the work at the forest experiment stations full correlation with related classes of forest research and lowest costs are insured.

Justification for this legislation lies in part in the growing importance of flood control in the United States. Major flood catastrophes are ordinarily taken into account only as detached occurrences and are soon forgotten. Lesser floods are often ignored and never considered in the aggregate. The flood situation of the United States is, therefore, far more serious and the necessity for control far more important than is generally realized.

Justification lies also in part in erosion losses which threaten to make man-made deserts of an enormous area of land and threaten seriously to reduce the productivity of another enormous area. Much of the process is so insidious and so inconspicuous that little realization exists nationally or even locally of what is going on and what it means.

Justification for this legislation lies in part in the fact that water for agricultural, municipal, power, and other uses is both the key to and the limiting factor in the development of the West. Recognition of the growing need for municipal supplies shows that water is also one of the most important factors in maintaining the development of the East.

Justification lies also in wide differences of opinion as to whether forest and other cover is a decisive factor in erosion and the regulation of stream flow. These differences range from flat rejection, through theoretical but passive acceptance, to full acceptance handicapped in detailed application to forest and range management by lack of knowledge. These differences are reflected in public demands as divergent as for the total destruction of the forest or chaparral or range cover, or its full protection against fire, cutting, and grazing. They are reflected in radically different policies or the entire lack of policies in the administration of public and private lands with watershed values. They are reflected in expenditures of hundreds of millions of dollars for flood control, the improvement of navigation, dams, and for municipal water supplies in which the possibilities of such influences are disregarded or variously recognized. In the last analysis these differences in opinion, demands, and action reflect the lack of knowledge which the proposed legislation is designed to supply up to the limit of Federal obligations. The existing watershed conditions in the United States which justify the enactment of this legislation are described in detail in another section of the report on Senate Resolution 175.

The provision for the Forest Survey in the McSweeney Act is probably the best that could have been obtained in 1928. The limitation of annual expenditures to \$250,000 drastically limits the rate of progress and inevitably extends the period required for completion. One unfortunate result will be the obsolescence of data for one region before it can be obtained for others. Furthermore, uncertainties and wide differences of opinion on forest policy continually emphasize the need for information which the Forest Survey is obtaining. In nearly every important forest region of the United States the depression has brought to light serious problems for the lasting solution of which the Survey alone can furnish the necessary information. A modification of the Research Act is therefore justified

in order to speed up the initial survey. Under the existing legislation the work must be discontinued as soon as the initial survey is completed. But it is becoming more and more clear that provision should be made for keeping the data current indefinitely. These considerations will soon justify another amendment to the Forest Research Act.

Closely related to the Forest Survey is another problem, land classification, the crucial importance of which as a great national enterprise is beginning to be appreciated only during the last few years largely as a result of the efforts of the Bureau of Agricultural Economics. Various classification activities have been under way for many years, such as the soil survey of the Bureau of Chemistry and Soils, and the classification of forest and agricultural lands in the national forests by the Forest Service.

Agricultural as well as and possibly more than forest land is involved in the national classification enterprise. The need for classification is indicated by maladjustments in land use which are particularly apparent during periods of economic stress such as the present. The evidences include widespread abandonment of agricultural lands, particularly of the submarginal class, often with tragic consequences to the owners; the breakdown of town and county governments which is one extreme local result of the nonpayment of taxes and land abandonment; an unregulated back-to-the-land movement growing out of unemployment, which in some instances promises to repeat the vicious cycle of attempts to use lands unsuitable for agriculture followed by later abandonment; and excessive erosion and disastrous floods following the cultivation of lands which should have been kept in forest. The information obtained in the Forest Survey, that obtained in other economic investigations, and also that obtained in forest management investigations, will necessarily have to be supplemented for the intelligent classification of forest lands. Integration of all pertinent information on the character of the land itself, what it can be expected to produce, and related economic and social questions must be insured in order to furnish satisfactory results.

Provision for Forest Service participation in the forest-land aspects of classification can be made either in an additional section to the McSweeney-McNary Act or as a part of a general authorization for all classes of lands. What funds will be needed is uncertain, because no attempt has been made as yet to work out detailed plans. As an approximation, however, it would be well to provide for annual increases of some such amount as \$50,000 or \$75,000 over a period of as many years as may prove necessary, which might reach five.

Substantial progress, particularly under the stimulus of the McSweeney Act, has been made in financing new research. Even though the depression does not force serious cuts in appropriations, and the authorization limits are reached in the fiscal year 1938, it is becoming more and more clear that by that time only a substantial beginning can be made toward covering the field necessary to meet Federal obligations.

In the Central Rocky Mountains, work is now confined to a small part of the silvicultural field and the experiment station is little more than a name. Outside of the United States proper no attempt has been made to establish the stations authorized for Alaska, Hawaii, or the West Indies. With present resources no silvicultural work can be done on many of the important forest types in the forest regions

in which experiment stations have already been established. On no single forest type is the present attack adequate. In only three regions is a sizeable attack on the forest-fire problem under way, and even in these it falls far short of what would be desirable.

In the important field of forest regulation no investigative work is now being done, as has already been indicated. There is a very distinct possibility of worth-while research contributions to forest engineering. Very little has as yet been attempted in the broad and promising field of forest genetics. Shade tree and park forestry is still another broad field which is hardly being touched, despite its place in the public interest.

Forest range investigations are confined to four western regions, in two of which work has been started only during the fiscal year 1932. In all of the remaining western regions the field is practically untouched. The range problem is also important in at least two eastern regions, the Middle West and the South. The southern problem, particularly that in longleaf pine, is triangular, involving range use and timber growing, and the relationship of fire to both. The possibilities of artificial reseeding of ranges and of the development through plant breeding of improved forage plants are being largely or altogether neglected.

Many additional experimental forests and ranges must be established to carry out the silvicultural, range, and erosion-stream flow investigations indicated, and all will require funds. In fact, with the funds now available it is not possible satisfactorily to handle the experimental areas already selected.

Economic problems growing out of changing conditions in forest and agricultural land use, in the possibilities of growing timber and other forest crops, and in the forest industries are, particularly during this period of financial stress, appearing far more rapidly than they can be solved. Long-established foundations are being swept away and what is to take their place is being left entirely to the play of blind forces. Other groups of problems which have important economic aspects arise out of the administration of large holdings of forest lands such, for example, as the national forests, and include forest regulation. The economic and sociological importance of forests in recreation is increasing rapidly as a result of such things as the automobile, good roads, and a large increase in leisure for practically all classes of people.

Forest products are falling behind in the competition with other materials because for one thing less is known of their properties and how to use them. It is conceivable that forest products research can be made one of the chief competitive weapons to maintain and increase consumption, and hence of an aggressive, constructive, plan-wise effort to make certain the use of forest land, and to keep available for public use a material of high intrinsic value. The indications are many that the time has come when such aggressive efforts are absolutely essential to insure full and satisfactory forest-land use. The effort of the Federal Government to maintain and enlarge the consumption of forest products is confined to forest products investigations. It is now and has always been seriously out of balance with the effort to grow timber.

A greatly enlarged scale of work in practically the entire utilization field is called for with particular emphasis on the chemical and

physical and other properties of wood on the most intelligent selection or use of wood in the light of these properties, on how to modify and adapt the properties for particular uses, and on the development of better design and assembly methods in building and construction which consumes over 60 percent of the lumber produced in the United States.

With work ahead of the magnitude and scope indicated, it is necessary upon the completion in 1938 of the 10-year period provided under the research act to look forward either to taking advantage of the lapse of the specified appropriation limitations, or to legislation for an entirely new financial plan. In either case, economic conditions permitting, regular increases should continue as fast as competent personnel can be obtained, until public needs and Federal obligations are met. Some classes of work can contribute so directly to the solution of acute depression problems that serious consideration of appropriation increases as emergency measures is justified. Among these are the Forest Survey and some other forest economic investigations, and various phases of the utilization problem. National losses from excessive erosion and unnecessary floods are already so great and the threat of still worse conditions so serious that special consideration is also justified for investigations of the use of forest cover for control. Belief that the amounts needed for emergency and for regular subsequent increases can and will be made available is merely an expression of confidence in the future of the United States. It is quite possible that experience may show the need for more additional sections of the act than have been indicated in order to provide satisfactorily for the work discussed.

Prospective financial needs for the decade beginning 1935 are forecast in the following tabulation. The first column of figures indicates the average annual increases needed for the various classes of forest research to carry out the financial plan prescribed by the McSweeney Act for its last four years, and also to provide for erosion-streamflow and land classification investigations. If, as now seems practically certain, economic conditions will prevent all but extreme emergency increases in 1934, the average for the four remaining years of the act will be correspondingly higher. The second column of figures indicates the average annual increases needed for the last six years of the decade:

Average annual appropriation increase

Appropriation item	Fiscal years 1935-38	Fiscal years 1939-44
	<i>Dollars</i>	<i>Dollars</i>
Forest management.....	115, 000	100, 000
Range investigations.....	40, 000	50, 000
Forest products.....	110, 000	100, 000
Forest Survey.....	(80, 000)	-----
Forest economics.....	45, 000	25, 000
Erosion-streamflow.....	100, 000	40, 000
Forest land classification.....	50, 000-75, 000	-----

The amount specified under the Forest Survey is that required to raise the appropriation to the existing authorization of \$250,000 in a single year. The research act should be amended to increase the maximum annual authorization to \$500,000 for the initial forest

survey. The increase of the appropriation to the higher authorization should not be extended over three years as a maximum. Provision should also be made for continuing the work necessary to keep data current after the completion of the first survey, and this may require a regular appropriation of approximately \$200,000 per year indefinitely, although the work might perhaps be done for less. The amount specified in the second column for erosion-streamflow investigation is that needed under the provisions of the proposed Leavitt amendment to the McSweeney-McNary Act.

The future trend of the work is almost certain, judging from past experience, to be from the extensive to the intensive, and from the general or exploratory to the fundamental. The easier and more obvious problems are gradually covered and a working basis of fairly satisfactory results furnished for current use, releasing men and resources for more intensive attack. The solution of the easier, more superficial problems and the growing intensity of actual practice leads inevitably to the fundamental how and why of biological phenomena, on the answer to which must depend fully satisfactory practice. Work over a period of years is bound to give a much clearer conception of what the underlying or key problem actually are and to emphasize the need for work on them. Men with the requisite training and experience are gradually developed or become available. Industrial concerns in such fields as forest products are gradually stimulated to undertake for themselves some of the simpler or application problems, thereby releasing the Federal investigative staff for the more difficult time-consuming fundamental work. This also promises to be true of the administrative force on the national forests in such problems as timber growing and protection, range management, etc.

Practically every consideration, therefore, emphasizes a gradual trend to more and more intensive attacks in all phases of forest research; and this makes adequate provision for working facilities, such as experimental forests and ranges, all the more necessary. The adoption of clear-cut objectives for such experimental forests and ranges within the past two years has materially speeded up their selection, which had previously been very slow. The number will have to be gradually but substantially increased. Energetic efforts will be necessary to insure the setting aside of some of the areas needed before they are seriously injured or ruined for experimental purposes by the cutting of the timber or other forms of use. These areas, particularly when they have a background of several or many years' work on many phases of the forestry problem, will offer ideal and in fact indispensable facilities for intensive work on fundamental problems. At the same time their value as demonstration areas will increase. Large numbers of investigations will be under way on contiguous areas, and integrated with them will be intensive studies to determine the why and wherefore of all that happens. Natural areas must also be set aside in advance of the ax and the saw.

The corresponding problem for forest products investigations will be simpler because of the recently completed laboratory at Madison, which will meet major needs for working facilities for some time to come.

Like all other publicly supported organizations, the Forest Service is dependent upon publications as one of the chief means for making

its results known. One of the great needs, not as yet satisfactorily met, is to publish results promptly so that the development of forestry will be stimulated as much as possible. What this calls for perhaps most of all is a medium of publication which will handle progress reports as they are completed. A progress report series, the numbers of which can be issued periodically or whenever the amount of material warrants, would go a long way in meeting the situation. It would undoubtedly have important incidental results in helping to maintain a high morale in the Research organization, particularly if investigators can be placed largely on their own responsibility for the material published.

Competent, well-trained men will probably continue to be the limiting factor in the development of most classes of forest research for some years to come, if economic conditions permit the expansion indicated in the preceding discussion. Efforts to maintain the highest standards possible in recruiting should be continued. Standards should in fact be raised as rapidly as this can be done. Every possible effort must be continued to stimulate the training of men before they are employed, and when it is necessary to take on men not fully trained, every possible means for developing them on the job and for allowing them ample opportunity to supplement their training at the universities must be utilized. The character of work done and, within limits, its amount will in the last analysis depend more upon the qualifications of the staff than on any other one thing.

It has not been possible to keep the growth of the Washington overhead of the Branch of Research in suitable ratio to that of the field staff. The result is that in this particular respect the development of forest research is probably more seriously handicapped than any other research in the Department of Agriculture. This is true both of number of men and their compensation. The fact that the work is in an entirely new field and that the training of personnel and the development of an organization are still in an early initial stage makes the need all the more urgent. As soon as the economic situation permits, this requirement should be met.

Many things on which a Federal forest research organization can and should render a large public service lie outside of the ordinary research projects and even outside of the ordinary research program. Periodically, for example, the need arises for the synthesis of results from many different lines of work in order to meet some exceptional public requirement or even some public emergency. Such a need now exists because of sweeping economic, industrial, and social changes, the ultimate outcome of which no one can foresee, but the importance of which no one denies. Because of these changes, much that has been accepted in the past in forestry, along with everything else, is now subject to uncertainty or attack. Some of the questions which are being raised regarding the present status and the future of forestry are unquestionably sincere. Others undoubtedly should be raised and must be faced. Others are undoubtedly intended to relieve private owners and industries of any and all responsibility for any contribution to future timber supplies, and tend to undermine the whole forestry movement. Some of these attacks are undoubtedly a part of the sincere and perfectly legitimate effort of overburdened taxpayers to eliminate unnecessary governmental functions or to reduce their cost. The purpose of other attacks seems, however, to

be to restrict the scope of governmental activities, to weaken the power and authority of government, and to relieve industry of public control.

One of the results is the unsettling of old objectives and the growing of a defeatist attitude concerning the possibilities and even the need for forestry. Another is that the attacks are beginning here and there to affect the development of forestry by the Federal Government, by States, and by private owners in such critical ways as appropriations or financial support.

Such situations as this call for an exceptionally broad and comprehensive handling. They call for a searching analysis of all the facts that can be obtained. They call for a reexamination of the public advantages of productive as contrasted with idle forest land. They call for a restatement of the whole forestry problem, of the program necessary for its solution, and of the Federal, State, and other public and private opportunities for the solution. All of this should help to clarify the atmosphere and, so far as may be necessary, to reorient the whole forestry movement. It should furnish the basis for constructive action along particularly broad and aggressive lines in order to insure the profitable use of forest land. It is nothing more nor less than this report on Senate Resolution 175 attempts to do, and for which the resolution affords the opportunity.

This is only one illustration of the big, far-reaching contributions which are periodically needed in such an enterprise as forestry, if it is to be kept an aggressively constructive and vital force in American social and economic welfare, and if the Federal and State Forest Services are to have the objectives which are absolutely essential to keep them as fighting organizations for the public interest. Contributions such as this must, however, be based on research technique, and the responsibility for them rests primarily upon forest research organizations, Federal and otherwise.

